

ANNUAL REPORT OF DIRECTOR OF SURVEYS

1926 - 7

Diagram

The general progress is illustrated on the accompanying diagram.

Fixed Point Network

Principal Trig.

Readjustment of the whole figure in two blocks divided by the line 25-28-32-86-84 is being proceeded with on the Egyptian value for the Imara Base.

Junction with the French Triangulation in the North has been further delayed.

3rd Order Trig.

The Plain of Esdraelon and a portion of the Samaria District has been covered with 3rd Order Work, 109 points having been established during the year, bringing the total up to 740 points covering 7800 sq. KM.

Minor Points.

The coastal plains from Gaza to Haifa have been completed up to the hills with Minor Triangulation, an additional 2030 4th-Order Points having been established, bringing the total including Traverse to 11580 points covering 4500 sq. KM.

Landmarks.

In addition 2300 subsidiary Landmarks have been accurately fixed upon cadastral boundaries during the year.

Large-Scale Surveys

Plane-Table Survey.

Work during the year has concentrated in the Jaffa Division, where the policy of preliminary demarcation of main cadastral boundaries has resulted in economy.

The whole of the villages in the Division with the exception of Petah Tikvah have been mapped, nearly 400,000 dunams of open lands on the 1/2500 scale and 49,000 dunams on the 1/5000 scale having been covered at average costs per dunam of 0.9 and 0.15 PT. respectively.

Chain Survey.

In the same area 74,000 dunams of close groves and fruit orchards have been surveyed by field-book and chain at an average cost, exclusive of examination, of 3.5 PT. per dunam.

Town Survey.

1/500 plans of house-property in Gaza covering 2110 dunams have been completed for assessment purposes, at a total cost, inclusive of Examination, of 83 PT. per dunam.

The work in this partly-ruined town has been very close and difficult.

Land Settlement

The cadastral partitioning of the Baisan Lands has proceeded, in conjunction with the Demarcation Commission, of necessity slowly. An additional survey party has been provided to meet a recent expansion in strength of the Commission.

About one-half of the whole area of the Baisan Lands has now been partitioned and handed over, and a considerable portion of the remainder is in hand.

Miscellaneous

Sale of Maps.

1145 Maps and 700 sun-prints were issued during the year, the sales realising £E.134.

Staff.

The health of the Staff has on the whole been very good, but one British Inspector and one European Sub-Inspector have been absent on prolonged sick leave.

The death of Mr. Michaelides, an experienced Grade II Greek Surveyor, by fall from a wall at Gaza on Sept. 27th, has been a much felt loss in the Department.

Training.

Intensive field training in the lowest grades of surveyors has continued and of 18 surveyor-apprentices engaged during the year 13 have become qualified producers.

An increase of draughtsmen, particularly in the Area Office, where skilled men are required, is needed.

Equipment.

Much difficulty is being experienced owing to climatic effects on tentage. The strength of the rot-proof material in the tentage supplied from England is not proving itself sufficient to withstand the wear and tear of continuous use in the field in this country.

Accommodation.

Hut-accommodation to relieve congestion in the Survey Office due to the requirements of Map Printing and Map-Storage is now a pressing requirement.



DIRECTOR OF SURVEYS.

CHL/MS
Jaffa.
30-11-26.

Survey of Palestine

PROGRESS DIAGRAM

31 December 1926

Showing

TRIANGULATION and LARGE-SCALE MAPPING

with Sheet Line System

(Rectangular Coordinates with Jerusalem Central Meridian)

Scale 1:750,000

KM 10 5 0 10 20 30 KM

Principal Trig. Points.

Area Covered by 3rd Order Trig.

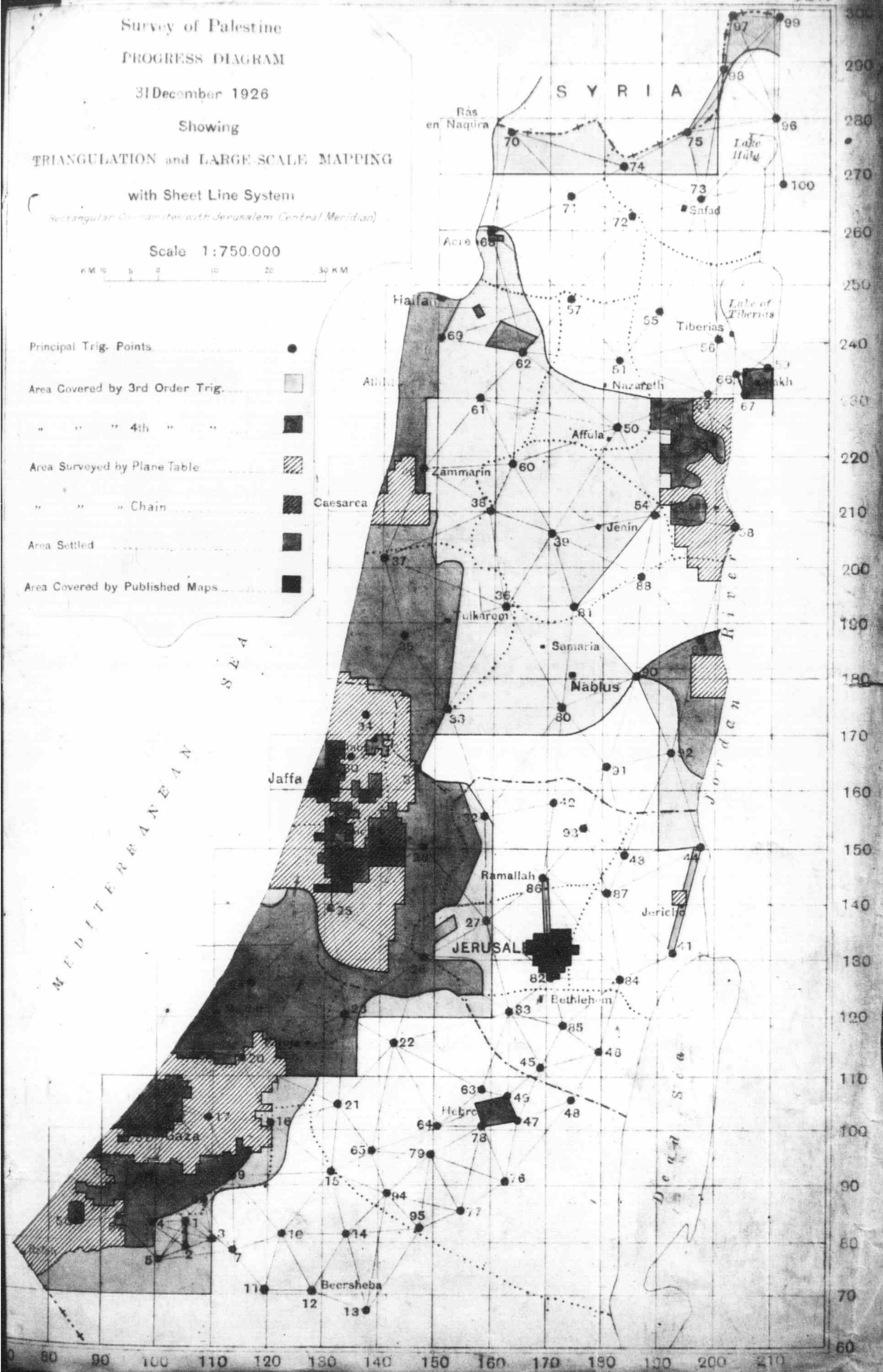
" " " 4th " "

Area Surveyed by Plane Table

" " " Chain

Area Settled

Area Covered by Published Maps



TECHNICAL SYSTEM.
SURVEY OF PALESTINE.

SURVEY OF PALESTINE

MEMORANDUM ON THE TECHNICAL SYSTEM OF THE SURVEY OF PALESTINE

(1) Introductory Remark.

The technical system of the Survey of Palestine has been evolved to fulfil a specific object in the most economical manner, and it is well in reviewing it to describe the main technical problems as they have in practice presented themselves, and so to begin at the costly business-end and trace back the influence of the conditions to those initial technical operations which are familiar in all scientific surveys.

(2) Past System of Registration.

As a result of a medieval system of Land Registration succeeded by war, only a fraction of the present owners of land in Palestine are registered, and as in addition the great majority of the cultivated areas are unmapped and largely featureless, and property has not been demarcated, such registrations as exist are usually not capable of interpretation on the ground.

Post-war land registrations have been accompanied by sketch-maps, but as enforcement of permanent marking in the open lands has only recently been possible, some of this work also has been liable to become of imaginary value, tending to further confusion.

The righting of this position is to be effected by Settlement Commissions which will investigate and decide upon all rights, and by a Cadastral Survey which will demarcate these upon the ground and record the same upon accurate plans which can accompany new registers.

(3) Objects of Survey.

The main ultimate object of the Survey has therefore been the economical production of large-scale cadastral plans correctly showing each individual parcel of land as registered.

But Registration by Land Settlement is a slow process not yet begun, present Land Registry transactions must continue and urgently need better location and control, the final cadastral operations need a large-scale topographical map and an accurate frame-work of permanent points upon which to operate, and the Administrative services much need maps for general purposes.

The more immediate object of the Survey has therefore been the production of large-scale topographic plans in advance of Settlement, with the fixation in plan and upon the ground of a sufficient frame-work of permanent

points to facilitate future property-demarcation, to which also the current work of the Land Registry can be hung.

(4) Scale of Maps.

Considerations of accuracy, of the value of land, the closeness of its sub-division, and the needs of registration, have caused the 1/2500 scale to be adopted as the standard scale for all the more fertile areas of the Palestine plains.

The relatively small areas of fruit orchards and groves, which are surveyed by field-book and chain, are plotted on this scale, which is suitable also for showing on the final cadastral plans the strip properties in the open Lands, - after partitioning and demarcation.

Larger scales are employed for close garden and village areas, and smaller scales for more barren or hilly areas where property is of much less value and sub-division usually less intense.

(5) Topography & Cultivation System.

The open cultivated plains are as a whole almost destitute of visible features other than numerous wadis and country roads, which are usually either ill-defined or subject to seasonal changes.

So also village boundaries and internal property boundaries are known to the fellaheen but seldom visible to others. The lands in each village are usually held on a collective basis, and are divided into permanent blocks roughly representing areas of different cultivable value. Each block is held by a family, a group, or by the whole village for a term of years, the members of such a group periodically subdividing into individual strip-parcels by lot.

A main object of the Settlement by Cadastral Survey is to substitute permanent individual ownership for this system.

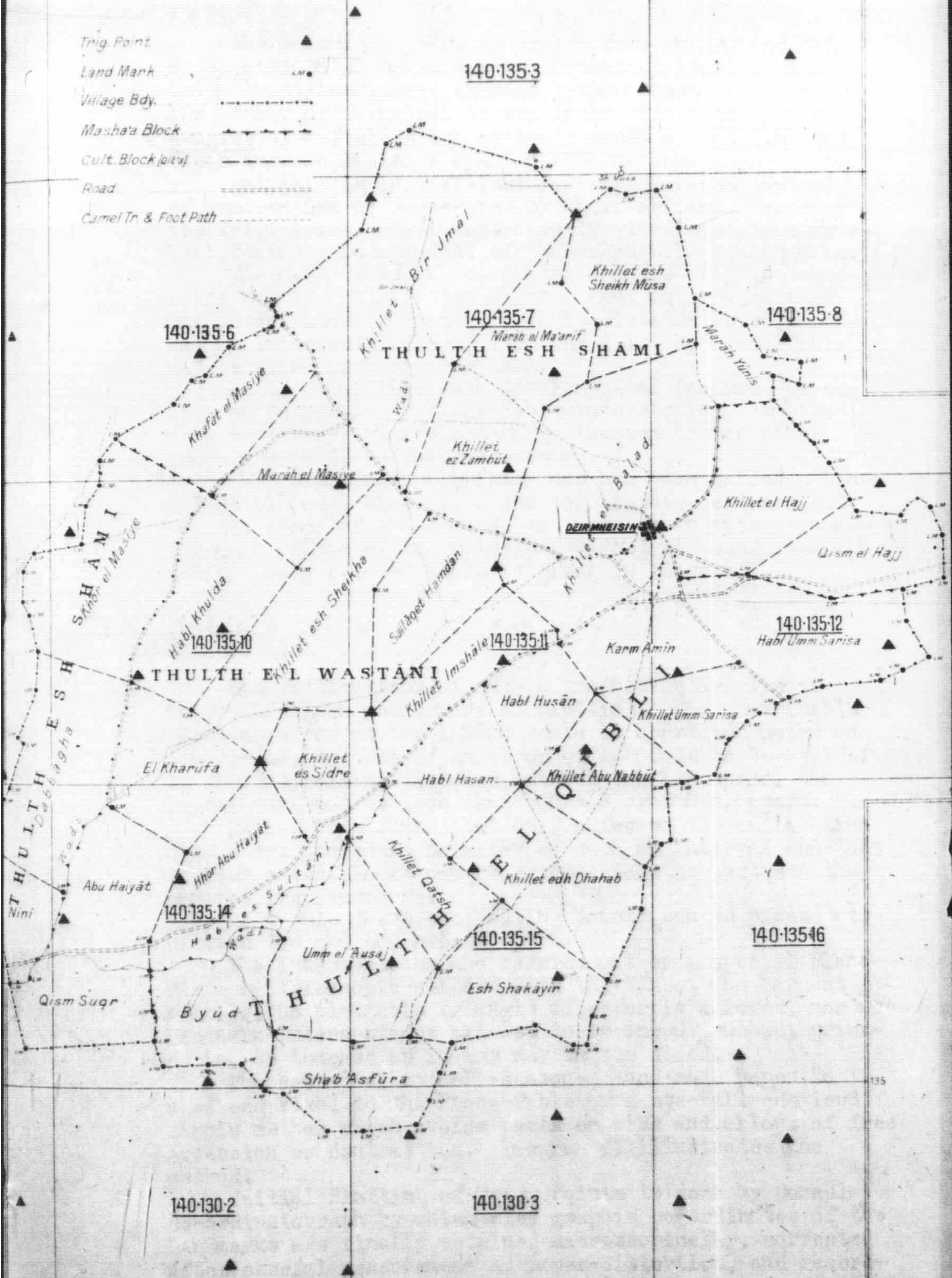
(6) Topo-cadastral Maps by Graphic Method.

Now this open country is exceptionally suitable for Triangulation and for the Plane-Table, but unsuited for Chain-Survey, although ultimate property demarcation must be with tape or chain.

The occasional patches of close orchards around villages which are surveyed with the chain being in any case plotted on the 1/2500 scale, the scheme that has been evolved for open lands depends upon a graphic method on a 1/2500 sheet-system.

DIAGRAM I

1:20,000 REDUCTION from the 1:2,500 P.T. TOPO-CADASTRAL Survey.



The principal Trig. is broken down by 3rd and 4th Order work to so close a network that at least 3 minor Trig. Points are fixed in each 1/2500 sheet. The average number of Trig. points available within the paper margins of a field sheet actually works out at 5.5, and their average distance apart at 890 metres.

But this is insufficient for rapid direct control of demarcation of properties by chain or tape, moreover the Trig. points are inconveniently sited upon topographical features independent of the cadastral requirements.

The main cadastral divisions are the village boundaries and the cultivation-blocks, and, after ascertaining these, Landmarks at a suitable distance apart which can be intersected direct from the Trig. by Plane-Table can be sited upon or near them.

At the same time such topographical features as exist can be put in by Plane-Table intersection, combined, when necessary, with close-range tachemetry or other graphic method, as found necessary.

The resulting preliminary map has been called a 'Topo-Cadastral' one, since it shows topographic features but not the shape of the ground, and also shows with accuracy the main points of the principal cadastral boundaries. An example on a reduced scale is given in Diagram I.

(7) Precautions with
Graphic Method.

The difficulties of such a graphic method lie in paper-shrinkage and errors of plotting. The unavoidable plotting error on the 1/2500 scale is about 1/2 metre on the ground, so that if an error of 1/500 is to be avoided in any controlling distance between two Landmarks, the latter must not be less than $500/\sqrt{2}$ or 350 m. apart.

It has been found that only a few of the cultivation blocks are too small to allow of such an interval and that in such cases blocks can be grouped together between the controlling Landmarks.

As a rule these controlling points can be placed at between 400 and 500 metres apart.

The intersections are carried out on a special Plane-Table by telescopic alidade with the finest and hardest pencils, no plottable triangle of error is allowed, nor are Landmark-intersections allowed to be inked, rubbed, pricked in, or touched up in any way in the field.

The best-quality well-seasoned hand-made paper is used and fixed to the Plane-Table by a specially-devised simple method which avoids paste or pins and allows of free expansion or contraction. Diagram II illustrates the method.

Initial Plotting of Trig. Points is done by Coradi Co-ordinatograph by which also graphic co-ordinates of the Landmarks are finally obtained microscopically, corrected after careful measurement of paper-distortion, and recorded.

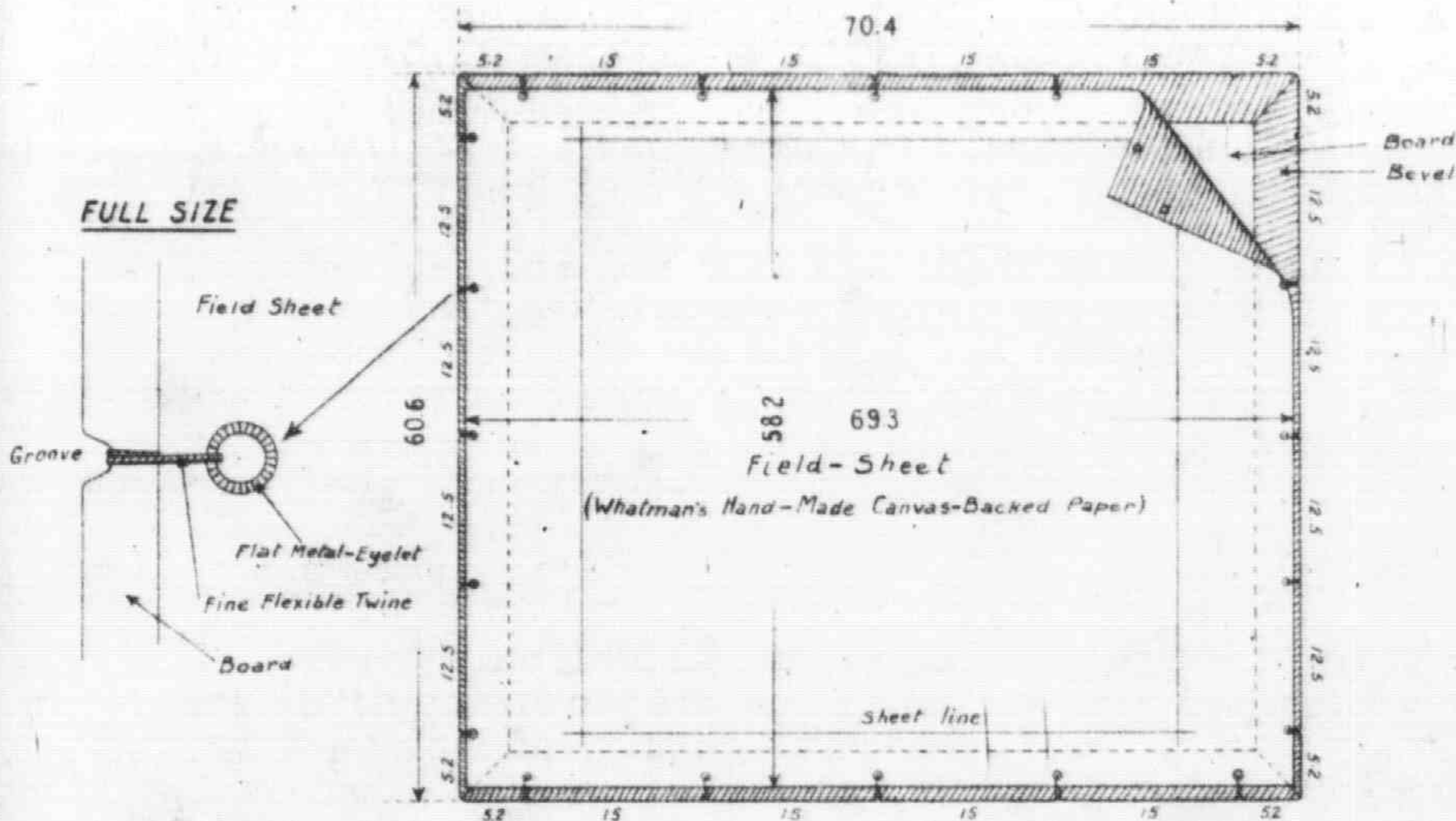
DIAGRAM II

PLANE TABLE BOARD

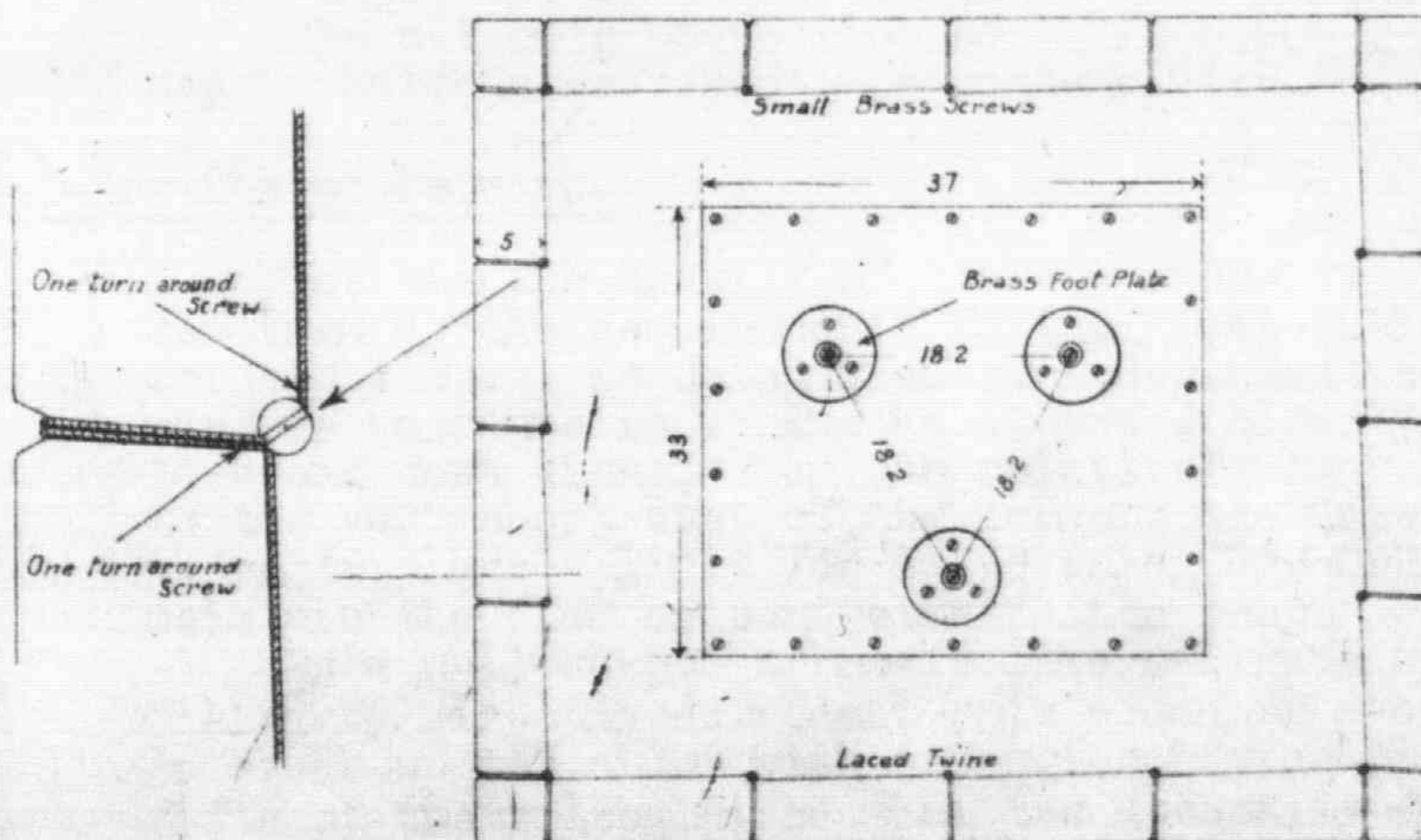
SCALE 1:8

DIMENSIONS IN CENTIMETRES

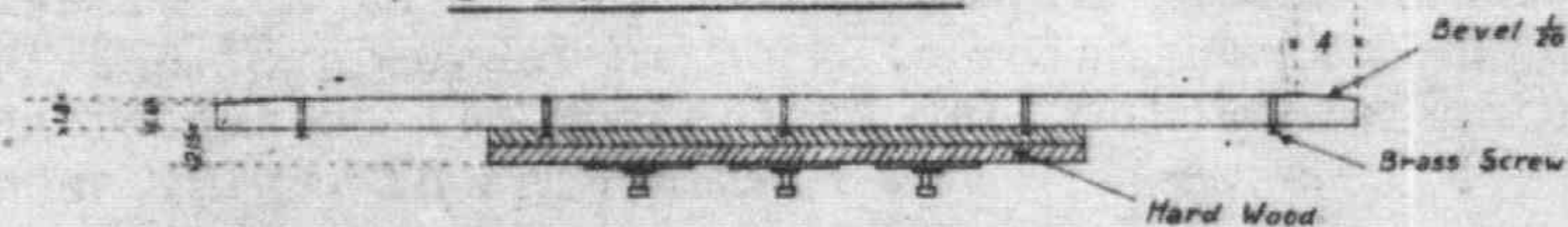
PLAN (Top)



PLAN (Underneath)



SIDE ELEVATION



(8) Accuracy of Graphic Method.

Careful tests of the accuracy of this method by tapings between Landmarks taken at random have been regularly made.

The resulting average of the 139 distances checked to-date is 445 metres and the average error of double-taping for that distance (calculated from Traverse closures on Trig. Points) is ± 0.22 metres. The average error of the graphic distances has on this basis been calculated from the discrepancies and found to be ± 0.3 metres, or 1/1483 (equivalent to a probable error of ± 0.25 metres, or 1/1780) nearly. *

It is considered that this result proves that the graphic fixations of the Landmarks are adequate for the control of detail errors and for the demarcation on the ground of individual properties with the chain.

Besides the low cost and the rapidity of the method, it has the great advantage of fixing the cadastral part of the frame-work so as to most likely be protected and maintained by the people, an important consideration in view of the curiosity of the Arab and the interval of time separating the initial from the final operations.

(9) Small-scale Maps.

The production of small-scale topographic maps is subsidiary to the main object but is ultimately assured by the necessity for maps for general purposes.

The 1/2500 field sheets are being reduced to a 1/20,000 scale as a reference map for administrative purposes, which, when funds and opportunity permit, can be quickly converted into a Topographical Series by completion with approximate contours. With Trig. heights already determined at less than a kilometre apart there should be little difficulty in such conversion.

The ultimate production of a 1/100,000 general topographic map in half-degree sheets is contemplated.

(10) Densities of Network.

Whereas the density of the 4th-Order Triangulation is determined by the requirements of the Plane-Tablers, that of the Principal Trig. is determined by independent considerations which must be untrammelled. And as it would clearly have been unsound to break down direct from the relatively long lines of the latter to the very short ones of the former, the question arose as to where to place a limit for intervening 3rd-Order work so as to maintain the flow of control with the proper economy.

In a well-shaped triangle internal gaps which cannot be filled by directly dependent points can be avoided by arranging to break up its sides with triangles having sides of about one-fifth of their length, so that the necessity for the insertion of additional points and for calculation of additional junctions, with liability to multiplication of errors, is eliminated.

It appeared therefore, from the geometry of the case, that the average length of side of a network should be about 5 times that of the lower-order network to which it is broken down, and this ratio has on the whole been well maintained between 3rd and 4th-Order Trigs. in Palestine.

*

Note:- The method compares well with that of Traverse in close areas. In the 56 check-tapings made between Traverse points in different but neighbouring Traverse Lines an average discrepancy of ± 0.23 metres between the taped and the calculated co-ordinate distances, in an average distance of 223 metres (1/970), was obtained. This is attributed largely to the unreliability of Traverse adjustments.

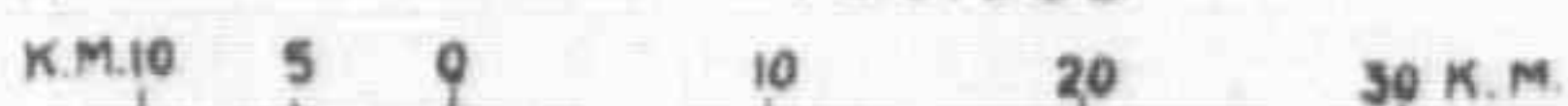
December 1926.

Showing

with Sheet Line System

(RECTANGULAR CO-ORDINATES WITH JERUSALEM CENTRAL MERIDIAN)

Scale 1:750.000



Principal Trig. Points

Area Covered by 3rd Order Trig.

" " " 4th "

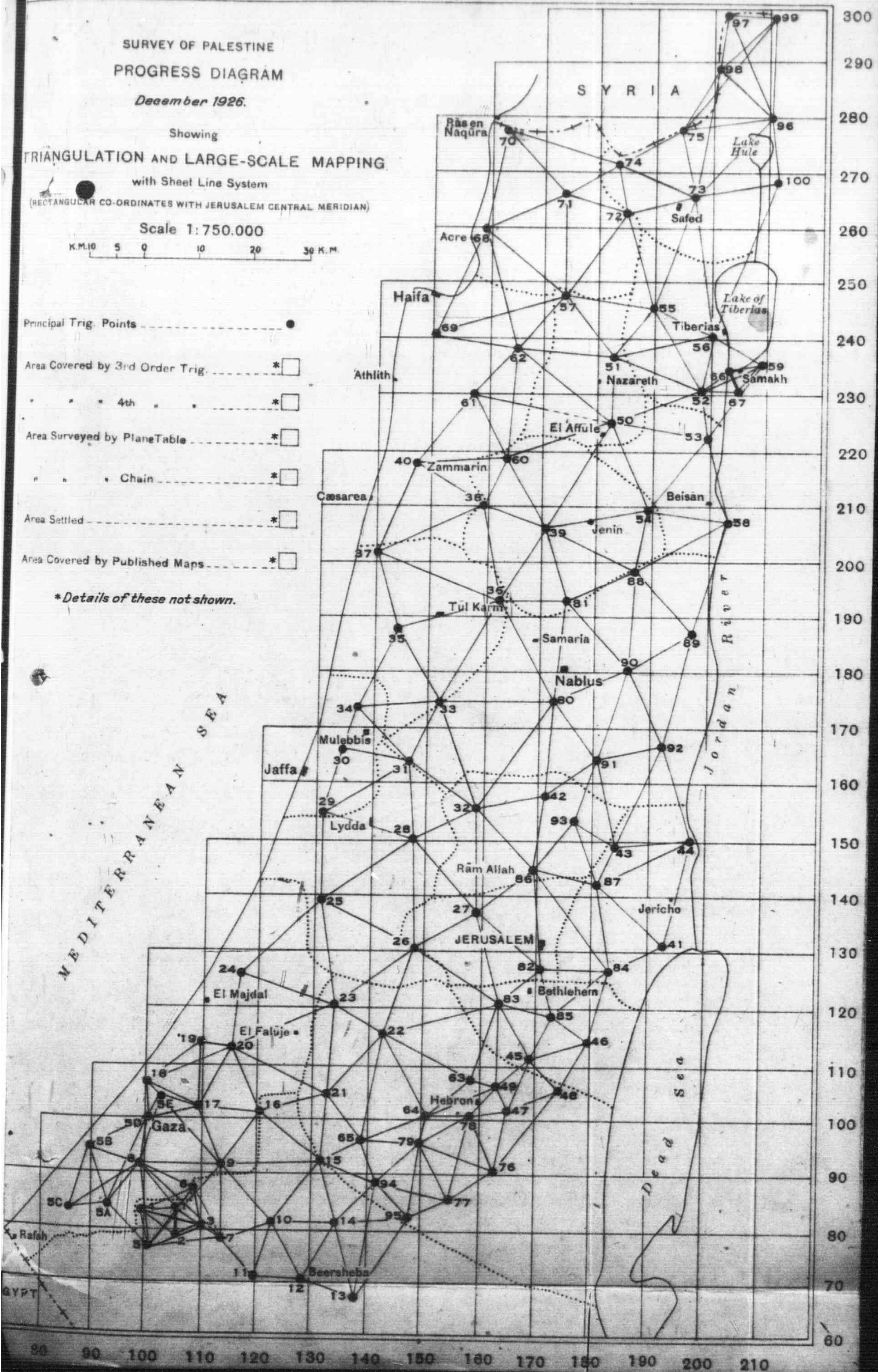
Area Surveyed by PlaneTable

Chain

Area Settled

Area Covered by Published Maps

*Details of these not shown.



The Principal Trig., however, has no superior control, its network has to cover the whole country, yet its errors must not accumulate much in any direction. It therefore has to be of high-class nature, with well-shaped figures, extended from a very accurate base-line, and the length of its sides becomes mainly dictated by the orography of the country, the atmospheric conditions, and the nature of the signals,- the latter matter having an important bearing on economy.

The Palestine Principal signals were fixed iron ones of modified S. African pattern at an average distance apart only a little more than 3 times that of the 3rd-Order Sides.

Geometrically speaking, therefore, the Palestine network would here appear uneconomical.

On the otherhand a more perfect geometric relationship between the side-lengths in the 3 Orders of Trig. which would probably have been possible would have given average side-lengths of 13, 2.5, and 0.5 KM. This might have substituted Trig. Points for many graphically determined Landmarks on the maps, but would by greatly multiplying the minor points have slowed down the whole of the Survey operations and heavily increased the total cost without justification.

The requirements of economy are in fact best served by putting any unavoidable additional capital expenditure in at the foundation of such a structure, where the amount required is least per unit of area covered.

(11) Observations and Instruments.

Following upon these considerations, it was decided that in order to maintain a regular progression in the accumulation of error propagated through the network, the number of balanced observations with the same class of instrument should vary roughly as the square root of the average distance between the signals in each Order of Triangulation.

With side-lengths of 1, 5, and 15 KM as originally thought possible for the 4th, 3rd, and Principal Trigs., respectively, 2, 4, and 7 complete sets of balanced observations on two faces with 5-inch micrometer theodolites would therefore have been theoretically suitable, but as an 8-inch instrument was thought necessary for the Principal Trig. the number of sets was reduced in this case to 6 - except in the case of the Base-Extension figure, where it was increased to 9.

The actual average side-lengths have worked out at 0.89, 4.20, and 13.20 KM in the three cases, so that the intended relationship was fairly well maintained.

Para (14) shows how far it may be said to have achieved its object in helping to control the rate of accumulation of error.

(12) Adjustment of Minor Trig.

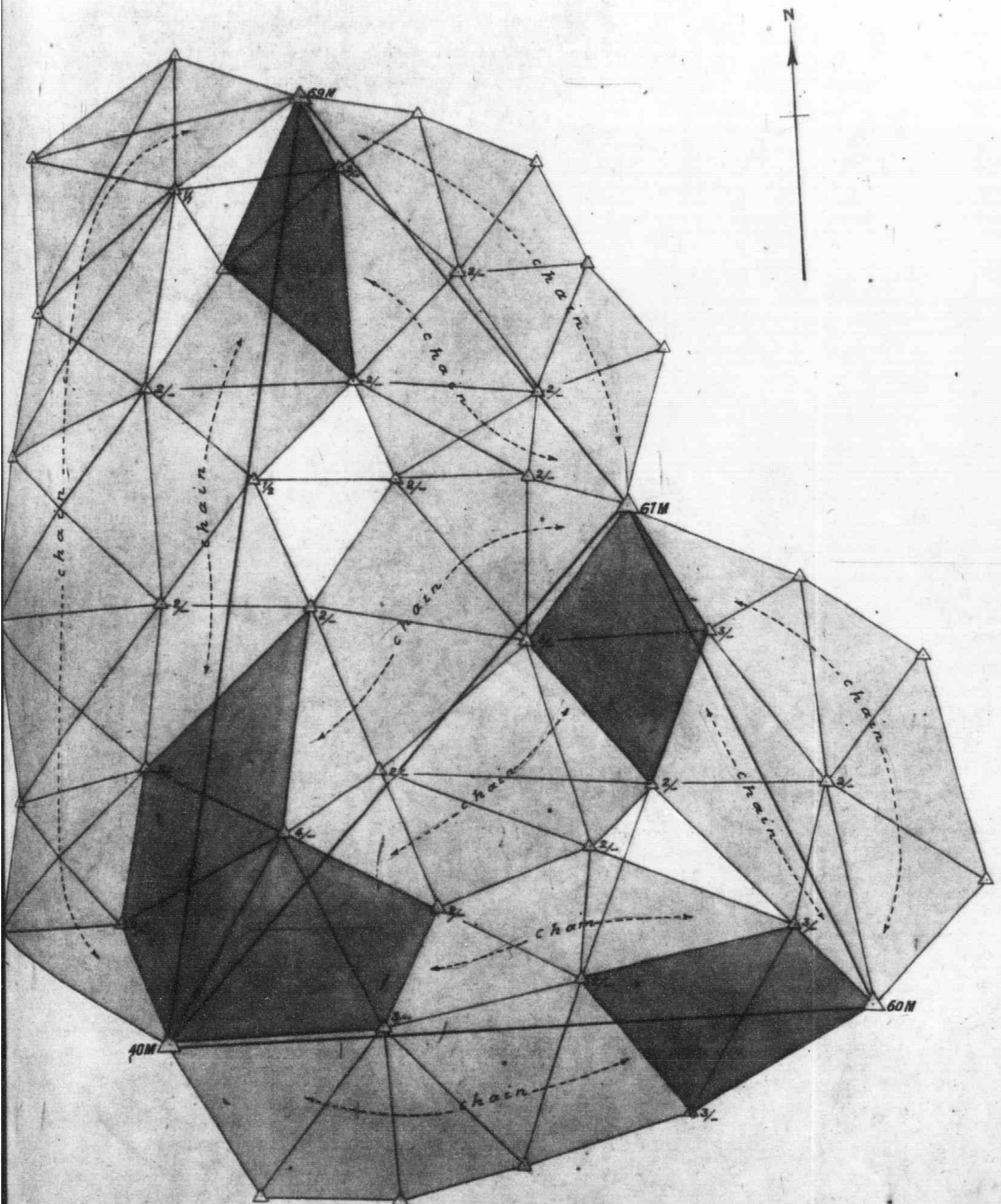
But the most important consideration in the due control of error is the system of adjustment.

The method at first adopted in Palestine was a borrowed one, which consisted of the application of a species of

DIAGRAM IV

ADJUSTMENT OF 3rd ORDER TRIG

- Principal Points..... $\triangle$
- 3rd Order Points..... $\triangle$
- Adjusted chains shown thus.....
- Nº of adjusted values taken for mean thus..... $\frac{2}{3}$
- Nº of unadjusted " " " " "..... $\frac{1}{3}$



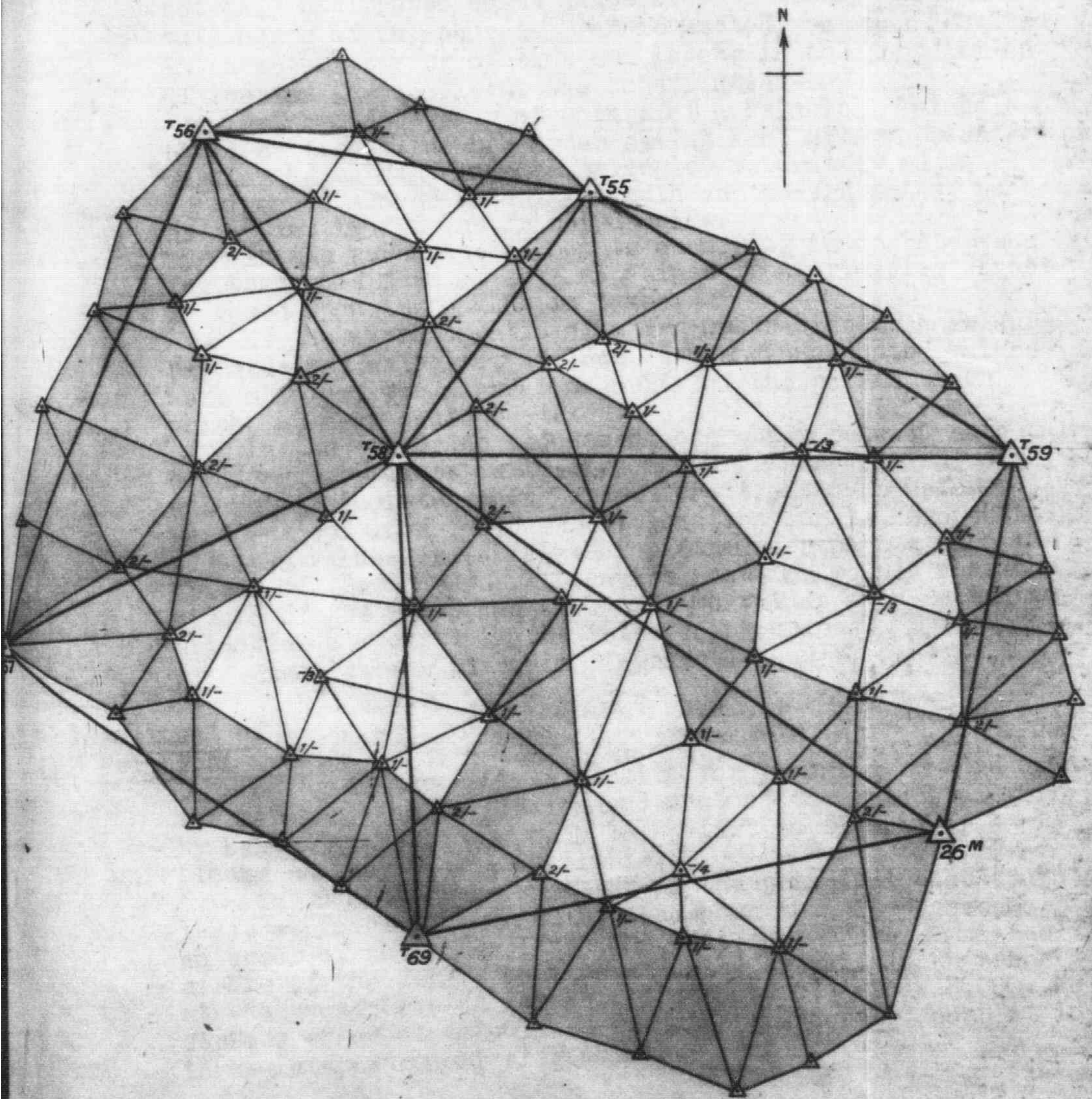
Scale... 1:126,720 or One inch to Two Statute Miles

0 1 2 3 4 miles

0 1 2 3 4 5 kilometres

DIAGRAM V ADJUSTMENT OF 4th ORDER TRIG.

3rd Order Points 
 4th Order Points 
 Adjusted chains shown thus 
 Nº of adjusted values taken for mean thus 2/-
 Nº of unadjusted " " " " " -/3



Scale 1:50,000

Metres 500 0 1 2 3 Km.

arbitrary angular adjustment of the lower-order network by polygons, followed by a scale-adjustment applied to one selected chain of triangles only between a single pair of points in each higher-order controlling triangle, - by means of a projection-method which resulted in approximations in both azimuth and in co-ordinates. *

The points in the relatively wide spaces between these approximately adjusted chains were obtained by separate solution of the simple dependent triangles.

The method was troublesome and was proved to be insufficiently accurate for cadastral purposes in Palestine by the frequent failure of Plane-Tablers to obtain accurate intersections at Landmarks, particularly in these loosely-controlled spaces.

The following more complete and rigorous system, which not only has proved quite successful in meeting all the requirements of an accurate graphic method, but has resulted in an actual saving of time and labour in the Computation Office and in the Field, was substituted:-

Between each pair of points of a Principal Triangle (held as fixed) two 3rd-Order chains are, after separate angular adjustment in each triangle, separately adjusted in rigorous manner both in azimuth and co-ordinates, so as to exactly fit the Principal side.

In the rare case of points occurring in an intervening space the mean of several values from triangles directly based upon the chains is taken.

As the average ratio of a 3rd-Order side to a Principal side was only $1/3$, at least two chain-adjusted values were obtained for a great majority of the points, from which the mean could be taken.

In the 4th-Order adjustment one chain between each pair of 3rd-Order points is in like manner rigorously adjusted, and points in intervening spaces are treated as before. Here, except in a few cases of junction points, two chain-adjusted values are obtained for 4th-Order points near the apices of the 3rd-Order triangles, one for points near the middle of the sides, and at least two values from dependent triangles at points in the intervening spaces.

Examples are given in Diagrams IV and V.

(13) Adjustment of Principal Trig.

Owing to the early necessity for pressing forward with the mapping, the original adjustment of the Principal Trig., by Least Squares could only be applied to figures or small blocks as they became available.

Subsequent re-measurement of the principal base (points 1-2), at Imara in the South, has shown that it possesses an error of the order $1/750,000$, but that the accumulated errors of the Trig., as thus adjusted, result in an error at the check-base at Semakh (points 66, 67) of $1/12,000$. No serious error of calculated azimuth was however found at intermediate astronomical stations.

*

Note: - vide 'The Cadastral Survey of Egypt 1892-1907' (Lyons), pp.260, 261, 280, 281.

It was considered that the acceptance of such an accumulated scale-error would prove ultimately awkward for the sheet-system in the North, and that as regular mapping could not for some time be commenced in the Northern District, the opportunity should be seized of more rigorously re-adjusting the whole Triangulation in two large blocks on the Egyptian value for the Imara Base, which has a probable error of the order 1/2,000,000.

(14) Accuracy of Fixed-Point Network.

The accumulation of error through the whole system as it affects the large-scale mapping operations can however be fairly assessed. In the following table evidence as to the progressive propagation of error through the Minor Trig. has been derived from the discrepancies between positions of junction points from different adjusted chains, as to that of the Cadastral network of Landmarks from actual measurement, vide para (8) above, and as to that of the Principal Trig., from the theoretic rate of accumulation of its average angular error.

TABLE I. Errors of Network.

Portion of Network	Average Triangular Error	Average length of a side.	Average scale-error.
Principal	± 1.4"	13.2 KM	± 1/70,000
3rd Order	± 4.9"	4.2 "	± 1/33,500
4th Order	± 10.0"	0.89"	± 1/10,500
Graphic	-	0.45"	± 1/1,500

(15) Astronomical Observations.

Observations for Latitude and Azimuth at the Imara Base (point No.2), checked by observations at points 31 and 73, have resulted in an almost constant difference of 1.4" between the Palestine and Egyptian values for latitude at a number of stations common to a triangulation carried out by the Survey of Egypt during the War.

The Imara value was considered preferable and has been adopted in the calculation of geographical co-ordinates.

A Longitude given by the Survey of Egypt at one of these common points, being considered as accurate as any fresh determination that could at present be undertaken, has however been adopted. It is ultimately based upon a meridian at Moqattam Hill determined by a Transit of Venus Expedition in 1874.

(16) Junctions with Geodetic Systems.

It is unfortunate that the valuable check upon the Palestine system that would have been afforded by the junction arranged for with the French Geodetic chain in the North has not yet been obtained owing to a delay in the latter operation.

A junction with the Egyptian Geodetic system awaits the extension through Sinai of the Principal Triangulation of Egypt.

(17) The System of Co-ordinates.

Rectangular co-ordinates (Cassini's projection) with a central meridian passing through point No.82 (Jerusalem) were decided upon. The sheet-grid shown in Diagram 4 is numbered from an imaginary zero-point in the Mediterranean, each grid-square comprising 64 sheets on the 1/2500 scale.

The fact that a figure of the earth (Bessel's) was used for the rectangular co-ordinates differing from that used for the geographical co-ordinates (Clarke's 1866) was due to the early need for mapping and the absence of tables of constants. The anomaly does not sensibly affect Cadastral requirements but it is proposed to eliminate it in the re-adjustment now being carried out by the adoption of the same Figure for all co-ordinates.

The systematic error due to the Projection is not included in Table I, and, with a Jerusalem Central Meridian, has practically negligible effect in the area between the Palestine coast and the Hedjaz Railway.

(18) Cost.

A de-novo survey for cadastral purposes is one for a practical economic object in which financial considerations are of the greatest importance, and the technical methods adopted have a governing influence on the cost.

A table is therefore added showing approximate figures for the cost up to date of the various sections of the work per unit of area, apart from that of preliminary training and of office work.

<u>TABLE II.</u>		<u>Field Cost.</u>	
		<u>Average Cost</u>	
<u>Section of Work.</u>		<u>£E. per Sq.KM.</u>	<u>Remarks.</u>
Principal Trig.....		0.58	*
3rd-Order "		0.56	
4th-Order "		4.84	
<u>1/2500 Topo-cadastral Mapping</u>			
Plane-Table (Open Lands.).....		10.00	(Includes Landmarks)
Chain Survey (Close Areas).....		77.00	(" Examination)
" " (Very Close, requiring			
/ Traverse).....		171.00	{ -do- -do- }
<u>1/500 Close Town Plans.....</u>		<u>913.00</u>	{ -do- -do- }

* Note:- Includes base-measurement, astronomical observations, reconnaissance, and cost of beacons.

The total cost of the 1/2500 preliminary map in open village lands is therefore £E.16 per sq.KM., and in ordinary close orchard areas £E.83 per sq. KM., on the average.

In considering these figures it should be remembered that the Survey Department is as yet immature and composed almost wholly of recently-trained and inexperienced local personnel, and that high prices for labour and material have ruled in Palestine in the post-war period.

Cuskey